STAN
Specialist Trauma Advisory Network of BC

BC Imaging Guidelines for Major Trauma

1. Preamble

The goal of this document is to establish provincial standards to facilitate the right imaging for the right trauma patient at the right time. The optimal management of major trauma requires that clinicians, radiologists, and other medical and technical personnel work seamlessly together to ensure timely and accurate diagnosis and treatment. This includes minimizing unnecessary imaging examinations and establishing consistent reporting procedures to avoid critical delays and to ensure that healthcare resources are used both effectively and efficiently.

This document is developed by and for medical imagers/imaging departments and trauma clinicians to enhance collaboration and communication. The interdisciplinary working group has outlined shared goals, mutual expectations, and comprehensive decision-making protocols to help ensure patient safety, optimal outcomes, and operational efficiency.

We define major trauma as serious injury due to externally applied forces that may result in death or serious disability. This document provides guidelines and recommendations for the imaging of known and suspected blunt and penetrating injury in adult patients (18 years or older) in order to establish standards of care and help ensure the delivery of optimal care. The content of this document reflects the consensus opinion based on current evidence and best practice of radiologists and specialist consultants from British Columbia's five regional health authorities. The creation of these guidelines was enabled by leadership from the Medical Imaging Advisory Council of British Columbia in collaboration with Trauma Services B.C. Funding for this work was awarded by the Specialty Services Committee of the Doctors of B.C. as part of its support for the project: Streamlined Specialized Care Strategies for Complex Major Trauma in B.C.

Participating stakeholders included:

- Medical Imaging
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    - BC Radiological Society
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- Emergency Services
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This document is the first of its kind in British Columbia. It is a living document to be adapted as best practices change and updated content becomes available. It is intended that these guidelines be jointly

maintained by MIAC and TSBC and that they reside with the Radiology Specialty Advisory Group of the TSBC's Provincial Specialty Trauma Advisory Network.

2. Guiding Principles

Collaboration and Excellence

1. Informed and respectful collaboration by the treating physician and radiologist helps to ensure that the medical imaging of the severely injured patient is appropriate and informative.

2. The mission of Trauma Services BC is to foster optimal performance of the trauma system across British Columbia. TSBC and the Medical Imaging Advisory Council of British Columbia jointly promote a standardized approach to high quality imaging and reporting in all provincial facilities that manage trauma patients.

3. Quality assurance and performance improvement with respect to the medical imaging of trauma is the purview of local hospital radiology departments and site trauma programs. Regional Trauma Programs, in collaboration with TSBC and the provincial Medical Imaging Specialty Advisory Group, are to provide oversight to ensure that provincial performance standards, where established, are adhered to. Appropriate indications for specific imaging, diagnostic yield, and management efficiency should, in general, be audited regularly.

Patient Safety and Efficiency

4. Definitive imaging should not be delayed by other less accurate investigations.
   Imaging studies that do not directly assist clinical decision-making are discouraged because they unnecessarily expose patients to the risks of transport and radiation and divert important resources from other patients.

5. Radiation exposure should be limited in all patients, particularly in the pediatric and pregnant population. A reasonable risk-benefit assessment must guide all imaging investigations in trauma patients. Consultation with attending radiologists to determine the preferred approach to imaging in complex situations is encouraged.

6. In the physiologically unstable or potentially unstable trauma patient, it is critical to complete and report required imaging with speed and efficiency as undue delays can lead to preventable disability and even death.

Imaging Principles

7. Standardized whole-body computed tomography (WBCT) imaging is appropriate in most patients injured by a major mechanism. WBCT extends imaging from head to pelvis in order to identify a wide range of clinically important occult injuries which are material in appropriate

triage and disposition planning. Early WBCT can currently be accomplished rapidly with a minimum of radiation exposure and frequently obviates the need for repeat imaging.

8. Standard Whole Body CT (WBCT) includes: head (non-contrast), cervical spine (non-contrast), CT chest with angiogram of the thoracic aorta (with intravenous contrast), and abdomen and pelvis (with intravenous contrast). Standard WBCT does not include: CT angiography (CTA) of COW, CT facial bones, CTA of carotid arteries, CT cystogram, rectal contrast, or CTA or CT of extremities. These are additional CT protocols that can be requested based on findings from initial imaging or clinical examination.

9. CT imaging for trauma should be performed using dedicated trauma protocols on a multidetector computed tomography (MDCT) scanner. CT acquisition should comply with the Ionising Radiation Regulations Safety Code 35 as set out by Health Canada.[1] Image reconstruction and reformatting techniques should be optimized to detect vascular, musculoskeletal and organ injury. CT scans that are incomplete, not properly formatted, or not transferred with the patient in the case of interfacility transfer create the need for repeated studies that are frequently unnecessary and wasteful.[2,3,4]

10. Intravenous contrast should always be administered when imaging the vascular system and/or abdomen and pelvis. There is a low risk for contrast-induced nephropathy in patients with history of pre-existing renal insufficiency, diabetes mellitus, nephrotoxic or diuretic drug administration. However, in major trauma setting where the clinical scenario warrants the use of contrast, renal function tests should be avoided as they introduce unnecessary delays in diagnostic imaging.

11. It is now widely accepted that CT imaging of the unstable trauma patient who has responded, even transiently, to resuscitation is appropriate and facilitates better clinical decision-making. This is only advisable when imaging studies can be completed within a reasonable delay with appropriate monitoring and medical supervision of the patient.

12. While awaiting transport, it is appropriate for sufficiently stabilized patients to undergo basic imaging (WBCT) at the referring site, provided this can be achieved with acceptable quality. If such imaging is pursued, it should be upon collaborative discussion between sending and receiving physicians.

13. Radiography and point of care ultrasound should be available in the trauma bay for hemodynamically unstable patients.

14. Magnetic resonance imaging (MRI) when available should have safe access for trauma patients with suspected spinal injuries and/or pancreatic injuries. Expedited access to MRI should be available for pediatric and pregnant trauma patients in an attempt to avoid other modalities which employ ionizing radiation.

Communication and Logistics

15. Prompt verbal and/or written preliminary and final reporting is essential for optimal management of patients. Standard template reporting helps to improve communication and

consistency. Transfers from a referring site should include reports on imaging obtained at that site.

16. As soon as it is considered likely that an acutely injured patient will be transferred to a higher level of care, or that external specialist consultation will be required, all imaging studies should be expeditiously transferred to the provincial PACS system for shared viewing to assist joint decision making. The B.C. Patient Transport Network (PTN) must be aware of available imaging and its availability for remote viewing when facilitating a clinical discussion between physicians.

17. The department where imaging is acquired requires monitoring and care capabilities appropriate for patients that are potentially unstable. Layout and design of imaging facilities for trauma patients must allow visual and electronic monitoring of patients by the responsible staff physician and treating team.

18. While imaging should never delay urgent transport of acutely injured patients to an already determined destination, it may be beneficial to delay transport to complete imaging at referring sites when results will materially influence determination of the preferred destination. However, transfers to a site for imaging only (i.e. not the site for definitive care) are to be minimized and, preferably, audited as a system-level performance measure.

3. Approach to Imaging in Major Trauma

Although injury patterns are often predictable, trauma is nonetheless associated with internal injury that may be subtle or occult, but still important. The clinical experience of emergency and trauma physicians caring for severely injured patients is elemental to the selection of appropriate imaging for patients with suspected injury.

There are four fundamental steps in medical imaging in the setting of major trauma:

1. Patient selection
2. Modality selection
3. Image acquisition and reconstruction
4. Report generation and communication

It is currently outside the scope of this document to make definitive recommendations on which patients should and should not be referred for medical imaging. However, we provide guidelines and recommendations, based on expert consensus, available evidence and best practices, for navigating these steps in imaging a severely injured patient.

A. Major Mechanism – Blunt Trauma

i. Stable Patient with Blunt Trauma

Key Recommendations

1. Patients with a major trauma mechanism who are stable and present with only minor injury should undergo whole body CT (WBCT-S).

2. Non-contrast CT examinations of the chest, abdomen and pelvis are considered inadequate, unless there is a history of allergy to iodinated contrast and other imaging modalities are not available.

a) Whole Body CT for Trauma – Stable Patient (WBCT-S)

Patients with high-energy mechanisms of injury should generally undergo whole body CT (WBCT) imaging with intravascular contrast but without oral contrast (see **Appendix A** for discussion of evidence and best practices for *Routine Whole Body CT*, *Intravenous Contrasts*, and *Oral Contrasts*). Arch-to-COW CT angiography is optional but is strongly encouraged as part of standard WBCT if there are clinical indicators (see **Appendix A** for discussion of evidence on *Arch-to-COW CT Angiography* and **Appendix B**

for a list of indicators for non-contrast CT of the head). WBCT-S identifies a number of important occult injuries which, critical or not, require diagnosis in order to assure optimal decision-making. While bedside imaging (radiography or ultrasound) declares pertinent positives and negatives that are essential to time-critical decision-making, WBCT provides the complete picture required to determine appropriate management, disposition, and follow-up.

Common important occult injuries not easily identified without WBCT include: intracranial hemorrhage, blunt cervical vascular injury, facial fractures, spinal fractures, rib fractures, pneumothoraces, blunt aortic injury, abdominal visceral injury and retroperitoneal hemorrhage. All of these can occur with high energy mechanisms in patients who appear to have only minor injuries.

Stable trauma patients undergoing WBCT do not routinely require the presence of a physician-led trauma team while the CT is being completed, although the standard monitoring requirement remains (See **Appendix C** for a list of triggers for ordering the "Standard Trauma Imaging CT Protocol").

Since CT imaging requires the patient to be removed from a monitored environment, minimizing the time between when the patient leaves the ED to imaging and when he/she returns to ED is essential for patient safety.

> **The target completion time for WBCT-S is 30 min. door-to-door** (from the time the patient departs the ED until he/she returns to ED).

The appropriate technical and reporting specifications for standard WBCT in trauma are described in **Appendix D** and **Appendix E**. See **Table 2** for a summary of WBCT protocols for stable blunt trauma patients, compared with protocols for WBCT in unstable patients.

b) Bedside Imaging for the Stable Patient

In general, radiographs are not recommended in stable patients where CT imaging is available, with the exception of pelvic XR. For suspected or confirmed pelvic ring fracture, plain film XR provides valuable diagnostic information that can inform clinical decision-making.

ii. Unstable Patient with Blunt Trauma

An unstable patient is any patient at high risk for physiologic deterioration. Commonly, though not exclusively, such patients present with:

- Hypotension,
- Hypoxia/respiratory distress, and/or
- Obtundation or impaired consciousness

a) Bedside Imaging for the Unstable Patient

Initial assessment of the unstable patient in the ED by the treating team focuses on the methodical completion of primary and secondary surveys to diagnose and treat imminently life-threatening conditions. Bedside imaging plays a key role in this process and should be limited only to studies that will meaningfully advance the care of the patient in an efficient and prioritized manner.

Selected bedside imaging studies targeting the presence of specific life-threatening conditions (e.g. hemorrhage, pneumothorax, hemopericardium) are appropriate prior to definitive imaging (CT) in unstable patients. In general, these studies include:

- Chest XR (supine)
- Extended Focused Assessment with Sonography for Trauma (E-FAST) (See **Appendix F** for E-FAST standards)
- Pelvic XR Targeted plain film X-ray

In selected patients, the following further studies may also be appropriate on an emergent basis in the ED during initial assessment:

- Urethrogram
- Lateral cervical spine plain X-ray
- Targeted plain film X-ray

The plain film imaging of extremity fractures and other studies not urgently required for the determination of imminently life-threatening or limb-threatening conditions should generally be deferred until definitive imaging

Table 1. Bedside Imaging Protocols in Unstable Blunt Trauma

Modality	Recommendations	
Chest XR (supine)	**Clinical**	Use to rule out critical diagnoses contributing to hypotension, including major pneumothorax and major hemothorax. If tension pneumothorax is suspected because of hypotension in the setting of absent/diminished breath sounds, respiratory distress, possible tracheal shift and/or hypoxia, then chest decompression should precede CXR. CXR is needed after placement of intrinsic tubes such as endotracheal or chest tubes. Other important findings will include stigmata of blunt aortic injury, diaphragm disruption, T-spine injury, major rib fractures.
	Reporting	See **Appendix E**
Extended Focused Assessment with Sonography for Trauma (E-FAST) **E-FAST (cont'd)**	**Clinical**	Standard E-FAST to visualize free fluid in the pleural, pericardial, perihepatic, perisplenic, and pelvic locations and pneumothorax in the anterior pleura. If CT not readily available, clinicians should consider E-FAST even in stable patients. E-FAST can be used to reserve OR suites, initiate massive transfusion protocol and establish ABC score. It is low cost and clinicians can benefit from maintaining their skill with this modality.

		If CT is readily available, however, clinicians should forego E-FAST as the latter does not contribute to decision-making. E-FAST is also useful in triage of multiple severely injured patients simultaneously.
	Technical	Abdominal visualization uses a 3.5MHz probe. Lung visualization uses a 3.5-7.5 MHz with B-mode imaging of the lung via the 4th or 5th intercostal space.
	Reporting	See **Appendix E**
Pelvic XR	**Clinical**	If the pelvis is mechanically unstable on initial assessment, or there is concern that occult pelvic injury is present and responsible for occult hemorrhage, then a pelvic binder should be applied prior to bedside pelvic imaging. If CT imaging is anticipated immediately following initial assessment, then plain XR of the pelvis is not indicated on an emergent basis. May also be useful to determine if pelvic binding is needed prior to transfer to CT.
	Reporting	See **Appendix E**
Urethrogram	**Clinical**	In the profoundly unstable patient with a clinically unstable pelvic fracture and clinical signs suggestive of urethral disruption (perineal ecchymosis, meatal blood, high-riding prostate), who is not responding to resuscitation efforts (non-responder) and is likely to proceed directly to OR from ED, a single cross-table urethrogram is rarely recommended if a gentle attempt at bladder catheter insertion has been unsuccessful. If no urethral disruption is identified, catheterization may be safely re-attempted. Otherwise urological consultation for urethroscopy/cystoscopy or intraoperative insertion of a percutaneous urinary catheter is required. The unstable polytrauma undergoing emergent surgery requires bladder catheterization to monitor response to intervention and resuscitation during surgery, and this is more difficult to obtain once the patient has left the ED.
	Reporting	See **Appendix E**
Lateral cervical spine plain X ray	**Clinical**	In the unstable non-responder with devastating injuries and GCS=3, who shows no evidence of extremity movement and for whom emergent transfer to surgery without CT imaging is being considered, a cross-table lateral c-spine may demonstrate atlanto-occipital dislocation or other severely displaced c-spine fracture, which portends a poor prognosis and thereby facilitates a decision not to proceed to surgery.
	Reporting	See **Appendix E**

b) Whole Body CT for Trauma – Unstable Patient Responding to Resuscitation (WBCT-R)

Just as for stable trauma patients with a major mechanism, unstable patients responding to appropriate resuscitation should also undergo WBCT in centres able to expedite CT imaging safely and efficiently. Any centre using WBCT for unstable responders must provide appropriate clinical monitoring and supervision by a physician-led trauma team during imaging.
WBCT studies for trauma may be augmented by additional focused CT imaging when clinically indicated by the finding of major extremity trauma on initial assessment. This may include focused CT imaging of joints and fractures with corresponding CT angiography to rule out associated vascular injury.

Expert clinical judgment, as always, is required to determine the suitability of expedited WBCT in unstable responders. The use of CT in unstable responders is well supported by current evidence (see **Appendix A** for discussion of evidence on *Whole Body CT in Hemodynamically Unstable Patients*).

Since CT imaging requires the patient to be removed from a monitored environment, minimizing the time between when the patient leaves the ED to imaging and when he/she returns to ED is essential for patient safety.

> **The target completion time for WBCT-R is 15 min. door-to-door** (from the time the patient departs the ED until he/she returns to ED).

c) Whole Body CT for Trauma – Unstable Patient Transiently Responding to Resuscitation (WBCT-U)

In some cases, initially unstable patients will respond to resuscitation only briefly or transiently (transient responders) indicating that more physiologically active injuries are present. The use of WBCT in these patients is more controversial, but still valuable and feasible if ongoing physiologic support can be maintained during imaging, and scanning can be completed extremely rapidly in a safe setting in direct proximity to the emergency department (see **Appendix A** for discussion of evidence on *Whole Body CT in Hemodynamically Unstable Patients*). In this instance, expedited WBCT is completed more quickly than standard WBCT for trauma and targets the presence of critical injuries that guide the Trauma Team Leader to make an optimally informed and prioritized management plan for the patient in extremis where a suboptimal disposition decision may be fatal.

The key diagnostic information sought in this instance is the presence or absence of:

- intracranial hemorrhage and intracranial hypertension
- cervical spine instability
- major blunt cervical vascular injury
- pneumothoraces
- blunt aortic disruption with contained or free extravasation
- major diaphragmatic tear
- major visceral injury
- unstable thoracolumbar fracture
- pelvic fracture associated with active arterial or venous hemorrhage

Since CT imaging requires the patient to be removed from a monitored environment, minimizing the time between when the patient leaves the ED to imaging and when he/she returns to ED is essential for patient safety.

> **The target completion time for WBCT-R is 15 min. door-to-door** (from the time the patient departs the ED until he/she returns to ED).

Table 2. Whole Body CT Protocols in Stable and Unstable Blunt Trauma

Modality		Recommendations
WBCT-S Whole Body CT for *Stable* patients	**Clinical**	Indicated for trauma patients who have presented physiologically STABLE and remained so. Standard monitoring required. The presence of a physician is not required.
	Technical	No oral contrast IV contrast Optional: Arch-to-COW CT angiography (see **Appendix B** for indicators) For details of Standard Trauma CT protocols, see **Appendix D.** Target completion time: **30 min.** (door-to-door from ED to imaging and back to ED)
	Reporting	See **Appendix E**
WBCT-R Whole Body CT for *Unstable* patients responding to resuscitation (responders)	**Clinical**	Indicated for trauma patients who have presented physiologically unstable but have RESPONDED to appropriate resuscitation. Standard monitoring required. Monitoring and supervision by a physician-led trauma team including nursing and respiratory therapy is required.
	Technical	No oral contrast IV contrast Optional: Arch-to-COW CT angiography (see **Appendix B** for indicators) For details of Standard Trauma CT protocols, see **Appendix D.** Target completion time: **15 min.** (door-to-door from ED to imaging and back to ED)
	Reporting	See **Appendix E**
WBCT-U Expedited Whole Body CT for *Unstable* Patients responding transiently to resuscitation (transient responders)	**Clinical**	Indicated for trauma patients who have presented physiologically UNSTABLE and have responded to appropriate resuscitation only transiently. Standard monitoring required. Monitoring and supervision by a physician-led trauma team including nursing and respiratory therapy is required.
	Technical	No oral contrast IV contrast For details of Standard Trauma CT protocols, see **Appendix D.** Target completion time: **15 min.** (door-to-door from ED to imaging and back to ED)
	Reporting	See **Appendix E**

B. Major Mechanism – Penetrating Trauma

Penetrating injuries occur when an object pierces the skin and causes tissue damage. These injuries are usually related to stab or gunshot wounds.

i. Stable Patient with Penetrating Trauma

Focused CT imaging of affected body region is recommended in stable patients with penetrating trauma. Depending on location of injury, intravenous, oral and/or rectal contrast may be recommended. We do not recommend WBCT in the stable patient with penetrating trauma.

In obese or extremely muscular patients with penetrating trauma or in cases of penetrating injuries to the back or flank, local wound exploration is important but can be unreliable. It is important to clearly mark entrance and exit wounds with a radiopaque marker prior to imaging to ensure accurate imaging of the wound. In the uncommon instance where a radiopaque marker overlying a wound may obscure important imaging detail by scatter (i.e. a neck laceration overlying the carotid artery or jugular vein), then the marker should be omitted.

Table 3. Focused CT Protocols in Penetrating Trauma

Modality	Recommendations	
Neck (CTA Neck with Contrast)	**Clinical**	Location of injury: By definition a significant penetrating neck injury violates the full thickness of the platysma. If platysma is intact the wound is considered superficial and does not require CT imaging. Neck is divided into three zones: ▪ Zone 1: Clavicle to cricoid cartilage ▪ Zone 2: Cricoid cartilage to angle of mandible ▪ Zone 3: Angle of mandible to skull base Recommended protocol/order: Patients who should be assessed with surgical exploration: ▪ Hemodynamic instability ▪ Expanding hematoma ▪ Active bleeding ▪ Air leak Otherwise patients can be assessed with contrast enhanced intravenous CT angiography to assess for: ▪ Vascular injury ▪ Esophageal injury ▪ Tracheal injury ▪ Salivary gland injury ▪ Neurogenic injury ▪ Osseous injury
	Technical	See **Appendix D**
	Reporting	See **Appendix E**
Chest (CTA Chest with Contrast)	**Clinical**	Location of injury: Clavicles to the sixth intercostal space anteriorly and between the superior and inferior angles of the scapula posteriorly. Recommended protocol/order: Intravenous contrast enhanced CT angiography of the chest.
	Technical	See **Appendix D**
	Reporting	See **Appendix E**

Thoraco-abdominal Region (CTA chest then A/P with Contrast)	**Clinical**	Location of injury: Nipple line superiorly, anterior axillary lines laterally, costal margins inferiorly. Recommended protocol/order: Intravenous contrast enhanced CT angiography of the chest to the level of the aortic bifurcation and portal venous phase intravenous contrast enhanced CT abdomen and pelvis.
	Technical	See **Appendix D**
	Reporting	See **Appendix E**
Abdomen and Pelvis Region (A/P with Contrast)	**Clinical**	Location of injury: Costal margin superiorly, anterior axillary lines laterally, inguinal ligaments inferiorly. Recommended protocol: Oral contrast. Portal venous phase intravenous contrast enhanced CT of the abdomen and pelvis.
	Technical	See **Appendix D**
	Reporting	See **Appendix E**
Back (CTA chest then A/P with Contrast)	**Clinical**	Location of injury: Tips of the scapulae superiorly, posterior axillary lines laterally, iliac crests inferiorly. Recommended protocol: Intravenous contrast enhanced CT angiography of the chest to the level of the aortic bifurcation and portal venous phase intravenous contrast enhanced CT abdomen and pelvis.
	Technical	See **Appendix D**
	Reporting	See **Appendix E**
Flanks (A/P with Contrast)	**Clinical**	Location of injury: Between anterior and posterior axillary lines, sixth intercostal space superiorly, iliac crests inferiorly. Recommended protocol: Portal venous phase intravenous contrast enhanced CT of the abdomen and pelvis.
	Technical	See **Appendix D**
	Reporting	See **Appendix E**
Extremities (CTA with Contrast)	**Clinical**	Location of injury: Arms and/or legs. Recommended protocol: Intravenous contrast enhanced CT angiography.
	Technical	See **Appendix D**
	Reporting	See **Appendix E**

ii. Unstable Patient with Penetrating Trauma

CT is contraindicated in hemodynamically unstable patients with penetrating trauma.

Prior to surgical exploration conduct:

- Chest Radiograph: Assess for pneumothorax

- E-FAST ultrasound: Assess for hemoperitoneum/hemopericardium/ pneumothorax (see **Appendix F** for E-FAST standards)
- Additional radiographs to identify penetrating objects and their trajectories (head, neck, etc.)

C. Imaging by Specific Injuries

This section provides imaging modality recommendations based on key injuries. Please see preceding sections for imaging modality recommendations based on mechanism of injury (blunt or penetrating) and patient stability (stable or unstable).

i. Key Injury: Spine

a) Lateral cervical spine plain X ray

- In the unstable non-responder with devastating injuries and GCS=3, who shows no evidence of extremity movement and for whom emergent transfer to surgery without CT imaging is being considered, a cross-table lateral c-spine may demonstrate atlanto-occipital dislocation or other severely displaced c-spine fracture, which portends a poor prognosis and thereby facilitates a decision not to proceed to surgery.
- A major c-spine fracture dislocation identified in this manner indicates a particularly poor prognosis in the severely head injured and/or elderly patient

b) Cervical Spine Series Radiographs

- Not indicated in the severely injured patient
- If radiography ordered based on Canadian C-Spine Rule (**Appendix G**) then minimum views needed:
  - lateral to include C7-T1
  - AP
  - Open mouth odontoid
  - Obliques not necessary

c) Standard Trauma Imaging CT Protocol

- The basic set of CT imaging that will most often be used and should be considered the starting point for CT imaging of the severely injured patient
- Includes cervical spine (non-contrast)
- See **Appendix C** for criteria for the ordering of this standard CT Protocol
- A normal CT is adequate to clear the cervical spine injury if:
  - CT of c-spine is normal, and
  - Patient is assessable neurologically (i.e., moves all four limbs), and
  - There is no clinical suspicion of cord injury

  If one or more of these conditions are not met, a neurosurgical consult for possible MRI of the c-spine should be considered.
- Abnormal CT of the c-spine can include:
  - Significant degenerative changes

        - Fracture
        - Suspected ligamentous injury
    - Conduct CT c-spine if there is head injury or in elderly patients with GCS<15

ii. Key Injury: Chest

Strongly consider grouping together chest, abdomen and pelvis for injury-specific imaging (see **Appendix A** for discussion of evidence on *Imaging Chest, Abdominal and Pelvic Injuries*).

a) Chest XR (AP supine)

- Needed after placement of intrinsic tubes, such as endotracheal or chest tubes
- To rule out critical diagnoses contributing to hypotension, including major pneumothorax and major hemothorax
- If tension pneumothorax is suspected because of hypotension in the setting of absent/diminished breath sounds, respiratory distress, possible tracheal shift and/or hypoxia, then chest decompression should precede CXR
- Other important findings include stigmata of blunt aortic injury, diaphragm disruption, thoracic spine injury, major rib fractures

b) Standard Trauma Imaging CT Protocol

- The basic set of CT imaging that will most often be used and should be considered the starting point for CT imaging of the severely injured patient
- Includes CT angiogram (CTA) of thoracic aorta with IV contrast.
- Non-contrast CT examinations of the chest is considered inadequate unless there is a history of allergy to iodinated contrast and other imaging modalities are not available.
- Criteria for the ordering of this standard CT Protocol can be found in **Appendix C**

c) Delayed Phase CT Imaging of Chest

- Generally not necessary
- Consider if patient is hemodynamically unstable and chest is suspected to be source of active bleeding
- Delay: 2-5 min. after injection

d) Volume Rendered Reconstructions

- For flail chest
- Can use data already obtained from initial CT

iii. Key Injury: Abdomen

Strongly consider grouping together chest, abdomen and pelvis for injury-specific imaging (see **Appendix A** for discussion of evidence on *Imaging Chest, Abdominal and Pelvic Injuries*).

a) Abdominal Radiograph (AXR) (AP supine)

- Generally not necessary if CT ordered

b) Standard Trauma Imaging CT Protocol

- Basic set of CT imaging that will most often be used and should be considered the starting point for CT imaging of the severely injured patient
- Includes abdomen with IV contrast
- Non-contrast CT examinations of the abdomen is considered inadequate unless there is a history of allergy to iodinated contrast and other imaging modalities are not available
- Criteria for the ordering of this standard CT Protocol can be found in **Appendix C**

c) Extended Focused Assessment with Sonography for Trauma (E-FAST)

- E-FAST is not necessary in primary or secondary surveys but if CT not readily available, clinicians should consider E-FAST even in stable patients. (E-FAST is low-cost and clinicians can benefit from maintaining their skill with this modality.)
- If CT is readily available, however, clinicians should forego E-FAST as the latter does not contribute to decision-making.
- Standard E-FAST (see **Appendix F**) to visualize free fluid in the pleural, pericardial, perihepatic, perisplenic, and pelvic locations or pneumothorax in the anterior pleura.
- Also useful in triage of multiple severely injured patients simultaneously.

d) Delayed Phase CT Imaging of Abdomen

- Generally not necessary
- Consider if patient is hemodynamically unstable and abdomen is suspected to be source of active bleeding
- Delay: 2-5 min. after injection

e) CT Urography/Intravenous Pyelogram (IVP)

- Generally not necessary
- Consider if patient has hematuria from a suspected urinary collecting system injury
- Antegrade with delays through entire urinary collecting system (15-20 min.)

f) Rectal Contrast

- Generally not necessary on initial imaging
- Consider in penetrating wound to the flank, especially when requesting follow-up CT
- CT Imaging not to be delayed if patient unstable
- Requires rectal tube

g) Oral Contrast

- Generally not necessary
- Consider in anterior penetrating wounds in the epigastric region to assess for gastric injury
- CT imaging not to be delayed if patient unstable
- Consider danger of aspiration if patient has a decreased level of consciousness or nasogastric tube to be used if patient unable to take voluntarily

iv. Key Injury: Pelvis

Strongly consider grouping together chest, abdomen and pelvis for injury-specific imaging (see **Appendix A** for discussion of evidence on *Imaging Chest, Abdominal and Pelvic Injuries*).

a) Pelvic XR (AP)

- If the pelvis is mechanically unstable on initial assessment, or there is concern that occult pelvic injury is present and responsible for occult hemorrhage, a pelvic binder should be applied prior to bedside pelvic imaging
- If CT imaging is anticipated immediately following initial assessment, then plain XR of the pelvis is not indicated on an emergent basis.
- May also be useful to determine if pelvic binding is needed prior to transfer to CT

b) Standard Trauma Imaging CT Protocol:

- The basic set of CT imaging that will most often be used and should be considered the starting point for CT imaging of the severely injured patient
- Includes the pelvis with IV contrast
- Non-contrast CT examinations of the pelvis is considered inadequate unless there is a history of allergy to iodinated contrast and other imaging modalities are not available
- Criteria for the ordering of this standard CT Protocol can be found in **Appendix C**

c) Extended Focused Assessment with Sonography for Trauma (E-FAST)

- E-FAST is not necessary in primary or secondary surveys but if CT not readily available, clinicians should consider E-FAST even in stable patients. (E-FAST is low-cost and clinicians can benefit from maintaining their skill with this modality.)
- If CT is readily available, however, clinicians should forego E-FAST as the latter does not contribute to decision-making.
- Standard E-FAST (see **Appendix F**) to visualize free fluid in the pleural, pericardial, perihepatic, perisplenic, and pelvic locations or pneumothorax in the anterior pleura.
- E-FAST is also useful in triage of multiple severely injured patients simultaneously

d) Delayed Phase CT Imaging of Pelvis

- Generally not necessary
- Consider if patient is hemodynamically unstable and pelvis is suspected to be source of active bleeding
- Delay: 2-5 min. after injection

e) CT Cystogram

- To be used in a clinical setting of suspected bladder rupture, which is usually associated with severe pelvic fractures and hematuria (see **Appendix A** for discussion of evidence on *CT Cystography*)
- If no Foley catheter has been placed by clinician, antegrade with delays through bladder (15-20 min.)
- If Foley catheter has been placed by clinician, can be retrograde
- If tolerable, administer retrograde contrast consisting of either:

- 300cc iothalamate meglumine injection USP 17.2% (Cysto-Conray®), or
- 300-500cc mixture of one part Iohexol (Omnipaque 350®) to 2.5 parts water

f) Volume Rendered Reconstructions

- For unstable pelvic fractures
- Can use data already obtained from initial CT

v. Key Injury: Extremities

a) Extremity radiographs

- Should not be routinely performed prior to CT if a CT has been requested
- Depending on clinical acuity these can be usually obtained safely after CT-imaging

b) CT Angiogram (CTA) of Extremities

- Indicated for avascular extremity (e.g. pulseless foot)
- Can be obtained at time of initial CT

c) CT Extremities for orthopedic injury

- Can be obtained after patient stabilized after treatment for initial CT findings

vi. Other Optional CT Protocols

a) Facial Bones

- CT head is not the equivalent of CT facial bones—facial bones are not typically included in a CT head non-contrast
- Head CT can be extended to include all of mandible and skull base in order to obtain CT of both head and facial bones in one acquisition
- Clinical evidence of facial bone injury
- Additional axial, coronal and sagittal series using bone algorithm are produced
- Required in facial trauma

b) CTA of Circle of Willis (COW)

- Clinical setting of headache with intracranial bleed (SAH) and minor trauma raising suspicion of ruptured aneurysm

c) CTA of Carotid Arteries and Vertebral Arteries

- Clinical setting of penetrating or direct blunt neck injury
- Screening criteria for blunt cerebrovascular injury (BCVI) available in **Appendix H**

D. Modality Selection

i. Radiographic Imaging

In principle, some radiographic imaging can occur after initial clinical assessment but prior to any CT imaging required. Radiographic imaging is primarily performed to ensure the patient is safe to proceed to CT medical imaging. It should be performed portably. However, radiographic imaging should not unduly delay more definitive imaging.

ii. Ultrasound

Extended Focused Assessment with Sonography in Trauma (E-FAST) scans on stable patients is not recommended if it will delay transfer to CT.

E-FAST has many valuable roles in severely injured patients including:

- Triage of multiple severely injured patients simultaneously, and
- Assessment of the hemodynamically unstable patient

Imaging using E-FAST, as with other forms of ultrasound, is operator dependent and local quality guidelines should be used to determine who is capable of performing these examinations.

iii. Multi-detector Computed Tomography (MDCT)

Multi-detector Computed Tomography (MDCT) is the imaging technique of choice for the definitive assessment in the trauma setting. CT scanning has markedly improved the clinician's ability to diagnose and define the extent of injury in patients with trauma.

However, the indiscriminate use of multiple CT scans for all trauma patients not only adds cost to the health care system but may also increase cancer risks for the patient later on in life. To reduce unnecessary or insufficient CT examinations, criteria-driven imaging requests can be used to determine the trauma patients' imaging needs. In the future, electronic decision support could be used to support the clinical decision process.

a) Standard Trauma Imaging CT Protocol

The basic set of CT imaging that will most often be used and should be considered the starting point for CT imaging of the severely injured patient. It consists of:

- Head (non-contrast)
- Cervical spine (non-contrast)
- Chest: CT angiogram (CTA) of thoracic aorta (with IV contrast)
- Abdomen and Pelvis (with IV contrast)

Criteria for the ordering of this Standard CT Protocol can be found in **Appendix C**.

Clinicians will help facilitate contrast-enhanced examinations if imagers are reading CT examinations remotely. Parts of the basic set of CT imaging can be removed if clinically indicated. For example, if GCS=15 in a patient with stabbing to the abdomen, then the necessity of the CT head could be questioned. This is outlined in **Appendix H**.

b) Additional CT Protocols

In addition to the Standard Trauma CT Protocol additional selective CT examinations or procedures could be added based on clinical indications or imaging findings. This can be ordered by the clinician or initiated by the imager. See **Appendix C** for indications and technical recommendations for Optional CT Protocols.

iv. Magnetic Resonance Imaging (MRI)

The need for magnetic resonance imaging (MRI) of non-pregnant adult trauma patients is usually limited to the cervical spine. Limited sagittal imaging through the thoracic and lumbar spine may also be performed if clinically indicated. A very small percentage of unconscious patients with normal CT scans of the cervical spine will have ligamentous injury (see **Appendix A** for discussion of evidence on *Occult Spinal Injuries*).

A reasonable approach to the clearance of the cervical spine in unconscious and likely intubated patients:

- A normal CT is adequate to clear the cervical spine of injury if:
  - CT of the cervical spine is normal and
  - patient is assessable neurologically (i.e. moves all 4 limbs) and
  - there is no clinical suspicion of spinal cord injury
- If one of these conditions is not met a neurosurgical consult for possible MRI of the cervical spine should be considered. An abnormal CT of the cervical spine can include significant degenerative changes, fracture or suspected ligamentous injury.

E. Computed Tomography (CT) Acquisition and Reconstruction

Standardized CT Protocols are difficult to produce in a province as large as British Columbia. There are many CT departments in the province each with unique local environments, including the type of CT scanner available in a given radiology department. The protocols that are set out here are to be used as guidelines to help CT departments produce high quality images given the equipment available to them. The overarching goal of these CT protocols is to eliminate the need to rescan patients, particularly those patients who are initially assessed, imaged and stabilized in one hospital but transferred to another hospital for more definitive care.

Minimum necessary hardware that should be available in a CT department performing trauma imaging should include:

- Multi-detector CT (MDCT): We recommend a minimum 16-slice in order to obtain isotropic voxels
- Power Injector: With associated consumables
- Intravenous contrast: Minimum 320 concentration

Table 4. IV, Oral, Rectal and Cystographic Contrast Protocols

Contrast	Recommendation
Intravenous contrast injection with a power injector	• 4-5cc/sec of 320-350 concentration for 120-150cc or equivalent iodine amount
Oral contrast	• Aqueous such as gastrograffin 500cc at 2% if patient is able to ingest • Mix 20cc gastrograffin (Telebrix®) with 460cc water for a total of 500cc • Consider administering through nasogastric tube if patient is unable to ingest (e.g. with decreased level of consciousness) • 250cc should be adequate to fill the stomach
Rectal contrast	• Requires rectal tube • Aqueous contrast such as gastrograffin 500cc at 2% through rectal tube • Mix 20cc gastrograffin (Telebrix®) with 480cc water for a total of about 500cc • 500cc should be adequate to fill the colon via a rectal tube

Cystographic contrast	• If tolerable, administer retrograde contrast consisting of either:
	  ○ 300cc iothalamate meglumine injection USP 17.2% (Cysto-Conray®), or
	  ○ 300-500cc mixture of one part Iohexol (Omnipaque 350®) to 2.5 parts water

4. Template Reporting

Template or standardized reporting as compared to free prose reporting is becoming more accepted in medical imaging. It allows a "checklist" mentality to ensure that all the information that the clinician is seeking with imaging is commented on. It also allows straight forward written communication with less ambiguity.[5] Template reporting can prevent the reinterpretation of CT scans when patients are transferred for care, thus saving time and resources.[6,7]

See **Appendix E** for a suggested template for reporting trauma CT imaging.

5. Appendices

Appendix A: Knowledge Synthesis

i. Routine Standardized Whole Body CT in Hemodynamically Stable Patients

The Royal College of Radiologists (UK) recommends whole body contrast-enhanced MDCT (WBCT) in all severely injured patients as a standard.[8] There is much debate in the literature whether the benefits of routine WBCT in major trauma patients outweigh risks associated with radiation exposure.[9,10] Most research on the topic has been observational, with a few prospective studies, that show WBCT is associated with reduced morality rate and shorter stay in the ED in major trauma patients when compared with selective imaging.[11,12]

The REACT-2 study is the first randomized controlled trial of immediate WBCT in major trauma patients. Initial findings from REACT-2 show that, while routine WBCT does not affect mortality rates among major trauma patients, it does detect more clinically relevant incidental findings when compared to selective CT imaging.[13,14]

ii. Intravenous Contrasts

The New Hampshire Trauma Medical Review Committee (US) recommends intravenous (IV) contrast for all routine CT scan of the abdomen and the pelvis. Waiting for serum BUN/Cr should not delay CT imaging with IV contrast.[15]

A major concern in IV contrast is the risk for contrast-induced nephropathy (CIN), an acute kidney injury associated with iodinated contrast medium where serum creatinine increases by ≥25% or >0.5 mg/dL within three days of IV contrast administration.[16] Reported incidence rate of CIN is low, ranging from 1.9% to 6.6%.[15,17,18,19,20] Risk factors for CIN include renal insufficiency, diabetes, presence of malignancy, old age and use of non-steroidal anti-inflammatory drugs (NSAIDs).[8]

Patients with pre-existing renal insufficiency, diabetes mellitus, or taking furosemide (Lasix) or nephrotoxic drugs may warrant caution in administering IV contrast for CT imaging.[15]

iii. Oral Contrasts

The Royal College of Radiologists (UK) recommends against routine use of oral contrasts, except in penetrating abdominal or pelvic injuries where injury to the bowel is suspected.[21] No difference in accuracy has been observed between CT administered with oral contrast and those without, and omitting oral contrast saves time and costs and decreases the risk of aspiration.[22] A protocol of omitting

oral contrast in abdominal and pelvic CT has been associated with lower radiology turnaround time and length of stay in hospital, without significant negative impact on patient safety.[23]

iv. Arch to COW CT Angiography

There is some early evidence of the benefits of including arch to COW CT angiography in routine WBCT. Langner and colleagues prospectively evaluated a CTA protocol of the head as part of a whole body CT work-up (n=368) and argue that craniocervical CTA can be easily integrated into a WBCT protocol. However, existing guidelines are more conservative in their approach.[24] The Society of NeuroInterventional Surgery recommends CT angiography to be performed on all patients who meet an institutional threshold for clinical stroke severity.[25] The Canadian Stroke Best Practice Recommendations indicate immediate arch to vertex CTA (or magnetic resonance angiography) in patients who present with suspected ischemic stroke.[26] See **Appendix B** for a list of clinical indicators for requesting arch to COW CT angiography.

v. Whole Body CT in Hemodynamically Unstable Patients

Although traditionally whole body CT (WBCT) had been contraindicated in hemodynamically unstable trauma patients, recent evidence suggests WBCT can be beneficial in unstable patients with minimal risk.[27,28,29] Most notably, in their large retrospective multicentre study of over 16,000 blunt trauma patients, Huber-Wagner and colleagues found WBCT to significantly increase survival in both hemodynamically stable and unstable patients.[30] Another study led by Huber-Wagner showed that proximity of the CT suite to the trauma room results in improved probability of survival of severely injured patients.[31]

Drawing on recent evidence, the Royal College of Radiologists (UK) recommends CT protocols for hemodynamically unstable patients and that EDs should be planned and designed to increase the numbers of trauma patients who are hemodynamically stable enough for WBCT (Standard 10).[21]

vi. Associated Injuries in Chest and Abdominal/Pelvic Trauma

The association between traumatic injuries to the abdomen and the pelvis has been shown.[32,33] There is some evidence that support the association between chest and abdominal/pelvic injuries to suggest the value of imaging all three areas simultaneously. Parreira and colleagues found 25% of patients admitted for pelvic trauma had associated thoracic injuries.[34] Similarly, Shannon and colleagues found 62% percent of injuries in the abdominal/pelvic region were associated with concurrent thoracic region injuries and 37% of thoracic injuries were associated with concurrent abdominal/pelvic injuries.[35] Furthermore, concurrent rib and pelvic fractures have been shown to indicate solid abdominal organ injury (42%) more often than rib or pelvic fractures alone (26% and 15%, respectively).[36]

vii. CT Cystography

The American Urological Association (AUA) and Societé Internationale d'Urologie (SIU) recommend retrograde cystography (plain film or CT) in stable patients with gross hematuria and pelvic fracture.[37,38] Similarly, the European Urological Association (EUA) recommends cystography in suspected bladder injury.[39] Studies comparing plain film and CT cystography show comparable rates of sensitivity, particularly for retrograde CT cystography (sensitivity 95-100%).[40,41] CT cystography has the added benefit of minimizing patient exposure to radiation by being administered concurrently with abdominal/pelvic CT[41] and diagnosing other injuries or causes of abdominal pain.[38]

viii. Occult Spinal Injuries

There is controversy around whether CT can detect critical non-skeletal injuries (i.e. ligamentous or vertebral disk), particularly in obtunded or unevaluable patients, and to what extent MRI scans should be used. The Eastern Association for the Surgery of Trauma (EAST) conditionally recommends clearing the C-spine in obtunded adult patients based on CT scan alone, based on the ability of high quality CT imaging to rule out critical injuries (average negative predictive value of 88.5%), high costs of MRI, and the risks associated with removing a patient from a monitored environment for additional imaging.[42] Systematic reviews have shown that 15-16% of abnormalities are detected in MRI scan after a negative CT result, with 0.3-0.7% of cases that lead to unstable C-spine injury.[43,44] A recent prospective study showed ligamentous injuries detected via MRI scan in 16.6% of unevaluable patients and/or patients with cervicalgia with initially negative CT scan results.[45]

Appendix B: Indications for Non-Contrast CT Scan of Head

If none of these conditions are met, consider not ordering CT scan of the head:

1. GCS <13 when assessed (irrespective of time post injury)
2. GCS <15 two hours post injury (discuss with surgeon)
3. Any deterioration in condition
4. Suspected open or depressed skull fracture
5. Any sign of basal skull fracture
6. Post traumatic seizure
7. Focal neurological deficit
8. >1 episode of vomiting
9. Amnesia >30 min. for events prior to injury
10. LOC or amnesia and any of:
    - Age >65
        - Coagulopathy (bleeding/clotting disorder or anticoagulation, e.g. warfarin)
        - High risk mechanism, e.g. pedestrian vs. motor vehicle/ejected from vehicle/fall >1m
    - Additional considerations in children
        - Early vomiting is more common but ≥3 episodes should be considered significant
        - Tense Fontonelle
        - Bruising, swelling, laceration >5 cm if <1 year old
            - NAI
            - Abnormal drowsiness
            - Anaesthetic and radiation relative risk/benefit. Consult with specialist.

Altered conscious level should be attributed to head injury until proven otherwise. The decision to CT should be applied regardless of the influence of intoxication.

Appendix C: List of triggers for ordering of the "Standard Trauma Imaging CT Protocol"

- MVA: Speeds >50km/h
- Falls: Heights >10 feet
- Assaults: GCS <13
- Stabbings: Through the peritoneum
- Pedestrian Struck: Thrown >10 feet

Trauma Activations

- Shock with BP <90 systolic
- Intubated patient
- Airway distress
- Respiratory distress with rate <10 or >25
- GCS ≤8
- Penetrating trauma to head, neck, torso
- Major pediatric trauma
- Amputations proximal to hand or foot
- Evidence of spinal cord injury

Trauma Consults:

- All patients requiring admission from trauma that have a significant mechanism (i.e. falls >3 feet in height, major deceleration injuries, pedestrian struck, explosions, etc.)
- This includes:
  - All traumatic head injuries requiring admission
  - All traumatic spinal injuries requiring admission
  - All orthopaedic fractures requiring admission that are caused by a significant mechanism (i.e. not falls from standing like a fractured hip, not isolated sports injuries like a fractured wrist or femur)
  - All patients with multiple rib fractures requiring admission, especially if there is a hemothorax or pneumothorax
  - All patients with fractured mandible requiring admission
  - All patients with suspected or known intra-abdominal injury from trauma i.e. hemoperitoneum, solid organ injury, bladder injury, etc.
  - Hangings
  - Drownings
  - Burns >20% surface area or significant electrical burns
  - All penetrating extremity trauma with possible vascular or neurologic injury

Appendix D: Standard Trauma Imaging CT Protocols

- All CT scans can be obtained helical with 1mm or less acquisition thickness in transverse plane
- Bold faced protocols are part of the Standard Whole Body CT protocol
- Where IV contrast is indicated, exception is made if patient has a history of allergy to iodinated contrast and no other imaging modality is available

Protocol	Clinical Indication	Contrast	Algorithm	Reformats (mm)	3D/Volumetric
HEAD PROTOCOLS					
CT Head Non-Contrast	Assess for traumatic brain injury	No	Standard	Transverse 2-3	--
			Bone	Transverse 2-3	--
Optional Head Protocols					
CTA Circle of Willis (COW**)**	Headache with SAH and minor trauma, query ruptured aneurysm	4-5cc/sec of 320-350 concentration for 120-150cc or equivalent iodine amount	Standard or Angio	Transverse 1-2 Coronal 1-2 Sagittal 1-2 Transverse MIP 5/1	--
CT Facial Bones/Mandible	Complex fractures involving facial bones and mandible	No	Bone	Transverse 1-2 Coronal 1-2 Sagittal 1-2	--
CERVICAL SPINE or NECK PROTOCOLS					
CT Cervical Spine Non-Contrast	If radiography ordered based on Canadian C-Spine Rule, minimum views needed: - Lateral to include C7-T1 - AP - Open mouth odontoid Obliques not necessary	No	Standard	Transverse 2-3	--
			Bone	Transverse 2-3 Coronal 2-3 Sagittal 2-3	--
Optional C-Spine/Neck Protocols					
CT Angiography Carotid Arteries	Penetrating or Blunt Vascular Cervical Injury (See **Appendix E**)	4-5cc/sec of 320-350 concentration for 120-150cc or equivalent iodine amount	Standard or Angio	Transverse 1-2 Coronal 1-2 Right and Left Sagittal Obliques 1-2	--

CT Angiography Carotid Arteries (cont'd)			Standard or Angio (cont'd)		
CHEST PROTOCOLS					
Chest CT Aortogram	Aortic and Chest injuries	4-5cc/sec of 320-350 concentration for 120-150cc or equivalent iodine amount	Standard	Transverse 2-3 Coronal 2-3 Oblique Aorta 2-3	Yes, for flail chest
			Lung	Transverse 2-3	--
			Bone	Sagittal 2-3 for Thoracic Spine	--
Optional Chest Protocols					
Delayed Phase CT	Consider if patient hemodynamically unstable and chest suspected to be source of active bleeding	Delay: 2-5 min. after injection	Standard	Transverse 2-3 Coronal 2-3	--
ABDOMEN and PELVIS PROTOCOLS					
CT Abdomen and Pelvis		4-5cc/sec of 320-350 concentration for 120-150cc or equivalent iodine amount	Standard	Transverse 2-3 Coronal 2-3	Yes, for pelvic fracture
			Bone	Sagittal 2-3 for Lumbar Spine	--
Optional Abdominal Protocols					
CT Cystogram	Suspected bladder rupture associated with severe pelvic fracture & hematuria Usually antegrade with delays through bladder, but can be retrograde if clinician places Foley catheter	If no Foley catheter, antegrade with delays through bladder (15-20 min. after injection) If Foley catheter present, can be retrograde with contrast: • 300cc iothalamate meglumine injection USP 17.2% (Cysto-Conray®), or • 300-500cc mixture of one part Iohexol (Omnipaque 350®) to 2.5 parts water	Standard	Transverse 2-3 Coronal 2-3	--

Delayed Phase CT Abdomen/Pelvis	Consider if patient hemodynamically unstable and abdomen/pelvis suspected to be source of active bleeding	Delay: 2-5 min. after injection	Standard	Transverse 2-3 Coronal 2-3	--
CT Urography/IVP	Consider if patient has hematuria from suspected urinary collecting system injury	Antegrade with delays through entire urinary collecting system (15-20 min. after injection)	Standard	Transverse 2-3 Coronal 2-3	
With Rectal Contrast	Consider in penetrating wound to flank Requires rectal tube	Aqueous contrast such as gastrograffin 500cc at 2% through rectal tube Mix 20cc gastrograffin (Telebrix®) with 480cc water for a total of 500cc 500cc should be adequate to fill the colon via a rectal tube		Given prior to portal venous CT scanning of abdomen & pelvis	--
With Oral Contrast	Anterior penetrating wounds in the epigastric region to assess for gastric injury Consider danger of aspiration if patient has a decreased LOC, or nasogastric tube to be used if patient unable to take voluntarily	Aqueous such as gastrograffin 500cc at 2% if patient is able to ingest Mix 20cc gastrograffin (Telebrix®) with 480cc water for a total of 500cc Consider administering through nasogastric tube if patient is unable to ingest (e.g. with decreased level of consciousness) 250cc should be adequate to fill the stomach		Given prior to portal venous CT scanning of abdomen & pelvis	--
EXTREMITY VASCULAR or MUSCULOSKELETAL PROTOCOLS					
Optional Extremity Protocols					
CT Angiography of Extremities	Pulseless or avascular extremity	4-5cc/sec of 320-350 concentration for 120-150cc or equivalent iodine amount	Standard or Angio	Transverse 1-2 Coronal 1-2	--
CT MSK Injury	Injured extremity Can be obtained when patient stabilized after treatment for initial CT findings	No	Bone	Transverse 1-3 Coronal 1-3 Sagittal 1-3	Reformat thickness dependent on joint/bone involved

Appendix E: Reporting Template

History (key injury details)			
Comparisons (pertinent prior imaging exams, with dates & location)			
Technique (WBCT protocol used)			
Additional Techniques (optional imaging protocol used)	☐ Facial Bones – notes: ☐ CTA arch to vertex/skull base – notes: ☐ CT Cystogram – notes: ☐ Rectal Contrast ☐ Oral Contrast ☐ CT aortic bifemoral angiogram – notes: ☐ CT Extremity – notes:		
Findings			
Head	Assess for: Hemorrhage, mass effect, midline shift (mm), brain herniation, brain injury, skull fractures		
	No Significant Abnormality?	Yes ☐	No ☐ (elaborate below)
Facial Bones	Assess: Orbits, sinuses, nasal bone/septum, zygomatic arches, pterygoid plates, maxilla, mandible, TMJs, temporal bones, skull base		
	No Significant Abnormality?	Yes ☐	No ☐ (elaborate below)
Cervical Spine	Assess: Alignment, fractures, spinal canal narrowing, soft tissue swelling		
	No Significant Abnormality?	Yes ☐	No ☐ (elaborate below)

<table>
<tr><td rowspan="2">Arch to vertex/skull base</td><td colspan="3">Assess: Aortic arch, carotids, VB system, COW, dural sinuses or soft tissue injury, extravasation of contrast</td></tr>
<tr><td>No Significant Abnormality?</td><td>Yes ☐</td><td>No ☐ (elaborate below)</td></tr>
<tr><td rowspan="2">Chest</td><td colspan="3">Vascular/Mediastinum: Assess for aortic injury, pneumomediastinum, mediastinal hematoma, pericardial fluid, airway injury
Lungs: Assess for lacerations, contusions, masses/nodules, extravasation of contrast
Pleura/Diaphragm: Assess for pleural fluid, pneumothorax, diaphragmatic tear
Other:</td></tr>
<tr><td>No Significant Abnormality?</td><td>Yes ☐</td><td>No ☐ (elaborate below)</td></tr>
<tr><td rowspan="2">Abdomen/Pelvis</td><td colspan="3">Liver/biliary: Assess for liver injury, segments involved, hepatic hilum involvement, biliary or gallbladder dilatation/rupture, extravasation of contrast
Spleen: Assess for splenic injury, % spleen involved, hilum involvement, extravasation of contrast, expanding subcapsular hematoma, AV fistula, pseudoaneurysm
Pancreas: Assess for pancreas injury, location, ischemia, % involved, extravasation of contrast
Renal/Adrenal: Assess for renal/adrenal injury, % kidney involved, hilum involved, extravasation of contrast
Peritoneum: Assess for free air or free fluid
Bowel Mesentery: Assess for hematoma, occluded mesenteric arteries, extravasation of contrast
Retroperitoneum: Assess for hematoma, vascular injury, duodenal injury, extravasation of contrast
Bladder: Assess for free fluid or contrast extravasation in cystogram to indicate bladder rupture, intraperitoneal or extraperitoneal
Other:</td></tr>
<tr><td>No Significant Abnormality?</td><td>Yes ☐</td><td>No ☐ (elaborate below)</td></tr>
</table>

Thoracic Spine/Chest Wall/Lumbar Spine/Pelvic Bones	Rib fractures: Assess for rib, clavicular, scapular or sternal fractures, flail chest Thoracic and Lumbar Spine: Assess for fracture, dislocation, spinal canal compromise, paravertebral hematoma Pelvis: Assess for pelvic fractures, hip joints, SI joints, pubic symphysis		
	No Significant Abnormality?	Yes ☐	No ☐ (elaborate below)
CT Extremity	Assess for: extremity bone, joint or soft tissue injury		
	No Significant Abnormality?	Yes ☐	No ☐ (elaborate below)
Aortic Bifemoral CT Angiogram	Assess for: arterial injury		
	No Significant Abnormality?	Yes ☐	No ☐ (elaborate below)

Appendix F: Extended Focused Assessment with Sonography for Trauma (E-FAST) Standards

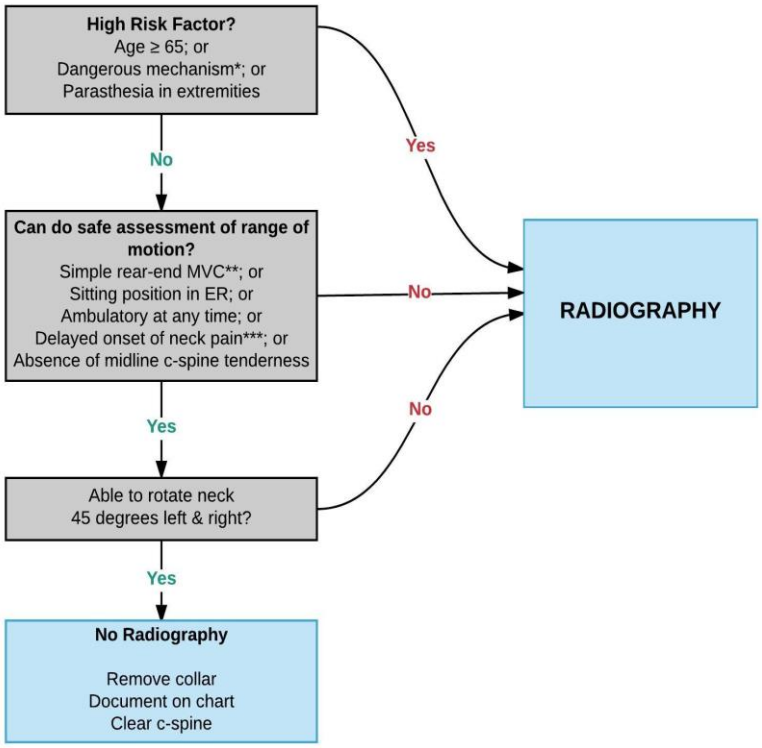
Criteria	Guideline
Patient Position	Supine and Trendelenburg optimal
Equipment	Well maintained ultrasound machine with both low and high frequency probes
FAST Component	Scanning of pleural, pericardial, perihepatic, perisplenic and pelvic locations
E Component	Scanning of the lung via the 4th or 5th intercostal space to identify signs of pneumothorax (absent lung sliding, absent seashore sign, bar code sign, B-Lines/comet tails)

Currently, clinicians do not require additional certification to conduct E-FAST. It is the recommendation of this Special Advisory Committee that clinician qualifications be endorsed for E-FAST.

Appendix G: Cervical Spine Imaging with Radiography following the Canadian C-Spine Rule

For alert (GCS=15, absence of intoxication/sedation) and stable patient where cervical spine injury is a concern (adapted from Stiell et al. 2003[46]).

Computed tomography (CT) is imaging modality of choice in obtunded patients (GCS<15) and in awake and alert patients who do not clear the Canadian C-Spine Rule. Cervical spine radiographs should have an extremely limited role in trauma imaging due to their relative lack of sensitivity for subtle fractures and injuries compared to CT imaging. Plain film x-rays are indicated only in settings where CT is unavailable and neurologic deficit is suspected based on physical exam, and only if imaging does not delay definitive care.



*Dangerous mechanism:	**Simple rear-end MVC does NOT include	***Delayed
- fall from elevation >= 3 feet (or 5 stairs) - axial load to head, e.g. diving - MVC high speed (>100km/hr), rollover, ejection - motorized recreational vehicles - bicycle collision	- pushed into oncoming traffic - hit by bus or large truck - rollover - hit by high speed vehicle	i.e. not immediate onset of neck pain

Appendix H: Screening Criteria for Blunt Cerebrovascular Injury (BCVI)

Screening Criteria for BCVI[47]

- Injury mechanism
  - Severe cervical hyperextension/rotation or hyperflexion, particularly if associated with:
    - Displaced midface or complex mandibular fracture
    - Closed head injury consistent with diffuse axonal injury
  - Near hanging resulting in anoxic brain injury
- Physical signs
  - Seat belt abrasion or other soft tissue injury of the anterior neck resulting in significant swelling or altered mental status
- Fracture in proximity to internal carotid or vertebral artery
  - Basilar skull fracture involving the carotid canal

Denver Modification of Screening Criteria[48]

- Signs/symptoms of BCVI
  - Arterial hemorrhage
  - Cervical bruit
  - Expanding cervical hematoma
  - Focal neurological deficit
  - Neurologic examination incongruous with CAT scan findings
  - Ischemic stroke on secondary CAT scan
- Risk factors for BCVI
  - High-energy transfer mechanism with
    - Lefort II or III fracture
    - Cervical spine fracture patterns: subluxation, fractures extending into the transverse foramen, fractures of the C1-C3
    - Basilar skull fracture with carotid canal involvement
    - Diffuse axonal injury with GCS ≤6
    - Near hanging with anoxic brain injury

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